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Visual Processing: Implications for Helmet Mounted Displays

~~(Reprint)~~

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Visual processing: Implications for helmet mounted displays

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ABSTRACT

A study was conducted to compare the performance of AH-64 (Apache) pilots to other Army pilots on visual tasks. Each pilot was given a task presented monocularly to the right eye, a task presented monocularly to the left eye, and a task presented to both eyes simultaneously in a dichoptic task. Results indicated no performance difference between the groups of pilots on the dichoptic task, but indicated better performance on the left monocular task for the AH-64 pilots. These results indicate that AH-64 pilots who are required to switch their attention from their left eyes to their right eyes in order to obtain needed information are capable of processing information efficiently and effectively using only one eye. The implications of these results for the Integrated Helmet and Display Sighting System (IHADSS) are discussed.

1. BACKGROUND

In June 1985, the U.S. Army began fielding a new rotary-wing aircraft, the AH-64 (Apache) helicopter. Integral to this advanced aircraft is a helmet-mounted display system known as the Integrated Helmet and Display Sighting System (IHADSS). The IHADSS includes a helmet, referred to as the Integrated Helmet Unit (IHU) (Figure 1), and various electronic sensing and control units. Mounted on the IHU is a monocular helmet-mounted display called the Helmet Display Unit (HDU)[1]. Imagery from a nose mounted infrared sensor and symbology representative of various aircraft parameters are provided to the pilot through the HDU. This information is presented to the pilot's right eye only; his left eye simultaneously receives disparate information from the cockpit and the external environment. Consequently, the pilot is required to process two separate sets of visual information presented to each eye simultaneously and is expected to process all of this information correctly and efficiently.

The ability of pilots to accomplish this information processing is of interest to the military aviation community, particularly the AH-64 training community. Many expensive training hours are consumed in teaching AH-64 students to use the IHADSS, which is unlike any system with which they have experience. In addition, there is a large variation in the minimum number of hours required for mastery of this system.

Verbal reports from some AH-64 pilots indicate the two sets of information presented when using the IHADSS are processed by switching their attention between the two eyes, attending to the separate sets of information as needed to safely fly the aircraft. However, other pilots report they perceive, and therefore process, the information simultaneously. The ability of pilots to rapidly switch their attention on demand to either eye or to process the two sets of information simultaneously is an important key to the IHADSS and flight performance with the AH-64.

It was hypothesized that experience with the IHADSS might improve pilots' abilities to process two different sets of information presented simultaneously to the separate eyes. This study was conducted as a preliminary investigation of how well AH-64 pilots experienced in the use of the IHADSS can process dual information sets presented simultaneously to each eye compared to pilots who have no experience with the IHADSS.

2. METHOD

2.1 Subjects

Twenty-four male subjects, ages 30 to 45, were recruited from the aviation community at Fort Rucker, AL. Twelve of the subjects were current AH-64 pilots with at least 900 hours of flight time and at least 100 hours of time with the helmet display unit; 12 of the subjects were non-AH-64 pilots with at least 900 hours of total flight time, none of which were AH-64 hours. Each pilot was tested for visual acuity using the Armed Forces Vision Tester, for accommodation using a Prince Rule, and for eye dominance using finger alignment on a fixed object; each subject had at least 20-20 vision (or corrected to 20-20 vision). Although some of the subjects were left eye dominant, a pilot study indicated eye dominance did not affect the performance of the particular task used in this study.

2.2 Apparatus

A Gerbrands three-field tachistoscope, Gerbrands model T-3B-2, was used to present the stimuli (Figure 2). The stimuli were presented on 4 in. X 6 in. cards supported by a black, nonreflecting background into which the cards were inserted via automatic card changers. Stimuli were viewed through half-silver mirrors. The viewing field was 3.5 in. X 5 in. at a distance of approximately 31 in. from the subject's eyes. The luminance was adjusted for all three fields by a Spectra Pritchard Photometer (Model 1980A-PL). A Gerbrands 300-C Digital Millisecond Timer (Model 03C6) was used to control the exposure duration of the stimuli for all three fields. In order to have separate viewing fields for each eye, linear polarizing filters were placed over the viewing fields with the rotated filters placed over the eyepiece so that each eye saw only one viewing channel. The fixation point was not filtered so that both eyes could view it binocularly. During the left eye monocular task, a flat black card was placed in the right eye viewing field, and the letters were shown through the left eye viewing port. During the right eye monocular task, a flat black card was placed in the left eye viewing field and the letters were shown through the right eye viewing port. During the dichoptic task, two letters were shown through the right eye viewing port and two letters were shown through the left eye viewing port. The spacing of the letters was such that the monocular task letters looked the same as the dichoptic task letters.

2.3 Stimuli

Letters were mounted on cards to be viewed by either the left eye or the right eye. The left and right monocular task letters were in a 2 X 2 matrix (Figure 3). The dichoptic task consisted of two 2 X 1 matrices of letters presented in each of the left and right visual fields, creating a 2 X 2 matrix. Each 2 X 2 matrix covered a viewing area of approximately 1.5 X 1.5 in., each letter 0.30 in. from the center of the card. The letters were block letter stencils (42 pt. Helvetica medium) rubbed onto white cards. The stimuli were divided into four categories: 25 percent of the letters had a left match, 25 percent of the letters had a right match, 25 percent of the letters had both a left and a right match, and 25 percent of the letters had no match on either the left or the right. The stimuli were approximately 0.7 degrees of visual angle from fixation point to the center of the letter horizontally (1.1 degrees total field), and approximately 0.9 degrees of visual angle from fixation point to center of the letter vertically (1.2 degrees total field).

2.4 Procedure

All subjects were tested between 1200 and 1600 hours. Upon arriving at the laboratory, the subject was taken to the testing room. Measures of left and right eye acuity, left and right eye accommodation, and eye dominance were made. The subject then was seated at the tachistoscope and instructed to look into the viewing port and lean his forehead against the edge of the port in order to maintain a constant distance from the stimuli. The subjects were not told the manner in which the letters would be presented (monocular versus dichoptic) to guard against any possible performance expectations of the subject. After the instructions were given for the test, the lights were dimmed in the room and the subject was allowed approximately 1 min. to adapt to the darkened room. Before each stimulus card was presented, the experimenter gave a ready signal after which the subject viewed a fixation cross presented binocularly for 1 sec.; the stimulus card was immediately presented for 20 msec. The subject responded verbally after each stimulus with one of four choices -- left match, right match, double match, or no match. If the subject was not sure of the correct answer, he was encouraged to guess. The experimenter recorded the subject's answer on a scoring sheet and any relevant comments from the subject.

A practice session comprised of 12 stimuli with an exposure time of 40 msec. was given before the actual test in order to train the subject on the task. The practice session was given monocularly to the dominant eye. After the practice, the test was given in 3 blocks of 20 trials; each block consisted of 20 stimuli presented to either the left eye only (left monocular task), the right eye only (right monocular task), or to both eyes simultaneously (dichoptic task). The order of eye presentation was randomized to counterbalance possible order effects.

3. RESULTS

Post hoc examination of the luminance levels of the left and right visual fields indicated the luminance levels were not equal. Investigation into the problem revealed the tachistoscope lamps were not reliable at the exposure interval (20 msec.) used in the present study. The differences in the luminance levels varied from approximately 0.04 foot Lambert to 0.23 foot Lambert difference, but with the extremely short exposure time used, a small difference in luminance causes a large difference in the performance of the tasks[2]. Therefore, the analyses were conducted to examine group differences for each task, but the comparison of performance between tasks could not be conducted.

Tests of skewness and kurtosis indicated the data were approximately normally distributed. The Levene's test for homogeneity of variance indicated there were unequal variances between the groups in the left monocular task ($F(1,22) = 7.59$, $p = .01$), therefore, the F test used for this task analysis was the Brown-Forsythe which does not assume equal variances[3].

Table I. Flight characteristics of each group.

	AH-64	Other
Flight hours		
Mean	3741.67	2819.25
SD	2379.25	1457.87
Maximum	9900.00	5500.00
Minimum	1400.00	900.00
HDU hours		
Mean	345.00	---
SD	173.30	---
Maximum	700.00	---
Minimum	125.00	---

Analyses also were conducted to determine if the two groups differed in flight hours, age, acuity, or accommodation. All tests indicated no significant differences in any of these variables (Tables 1 and 2). Additional analyses further indicated there was no significant relationship between any of these variables and the performance on the visual tasks. These demographic variables were therefore not included in the remaining analyses.

The performance data for each task were submitted to a 2-way analysis of variance (ANOVA) using BMDP7D[4]. Results of the ANOVA for the left monocular task indicated a main effect for group (Brown-Forsythe $F(1,13) = 8.80$, $p = .01$). The results of the ANOVA for the right monocular task and for the dichoptic task did not reveal any differences between the groups (right: $F(1,22) = 0.89$, $p = .36$; dichoptic: $F(1,22) = 0.07$, $p = .80$). However, visual inspection of the data indicated a trend for the AH-64 pilots to perform better on the right monocular task than did the other pilots (Figure 4).

4. DISCUSSION

The results indicated there were no significant differences in the performance on the dual visual task between AH-64 pilots experienced in processing dual visual information and other pilots not experienced in processing such information. However, a difference was found between these two groups of pilots on the left monocular task; the AH-64 pilots performed significantly better on this task than did the other pilots. A trend for the AH-64 pilots to perform better than the other pilots on the right monocular task also was found.

The inability of experienced pilots to perform better than nonexperienced pilots on the dichoptic task is contrary to what was hypothesized. The reason for this occurrence may be that the task used was not a sensitive dichoptic task, or that it did not represent the type of task an AH-64 pilot performs when using the IHADSS. However, the difference in

Table II. Vision characteristics of each group.

	AH-64	Other
Age (in years)		
Mean	35.92	36.00
SD	4.12	4.07
Maximum	43.00	42.00
Minimum	31.00	31.00
Acuity (Snellen)		
Right eye		
Mean	10.33	10.33
SD	0.86	1.19
Maximum	11.50	11.50
Minimum	9.50	8.50
Left eye		
Mean	10.46	10.29
SD	0.81	1.29
Maximum	11.50	12.00
Minimum	9.50	8.50
Accommodation (in centimeters)		
Right eye		
Mean	14.61	15.13
SD	5.69	6.80
Maximum	30.10	30.30
Minimum	9.20	6.40
Left eye		
Mean	13.73	14.11
SD	4.35	6.17
Maximum	24.50	27.50
Minimum	9.10	6.50

the ability of AH-64 pilots to perform better than other pilots on the monocular task is worth noting. These results indicate pilots trained to view the environment one eye at a time are capable of performing a single-eye task better than pilots who are using binocular vision while flying. Some AH-64 pilots verbally reported they "shut down" one eye so they may concentrate on the information being seen in the other eye. Present results indicate this ability may translate into better performance when information is presented monocularly. It would appear from this information that pilots do learn to manipulate their attention in whatever way is required in order to safely fly their aircraft.

It is difficult to generalize these results to the performance of pilots using the IHADSS. The question which this study addressed was whether AH-64 pilots could perform dichoptic tasks better than other pilots. In order to determine more about how the IHADSS is useful to the pilot as well as how he uses this system, more research is needed in the area of single modality dual task performance. Many years of research have been devoted in determining how visual information is processed. This research now should be applied to the aviation community to determine the best way a pilot can have information presented in a way which will be processed quickly and efficiently.

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Disclaimer: The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Army policy, or decision, unless so designated by other official documentation.

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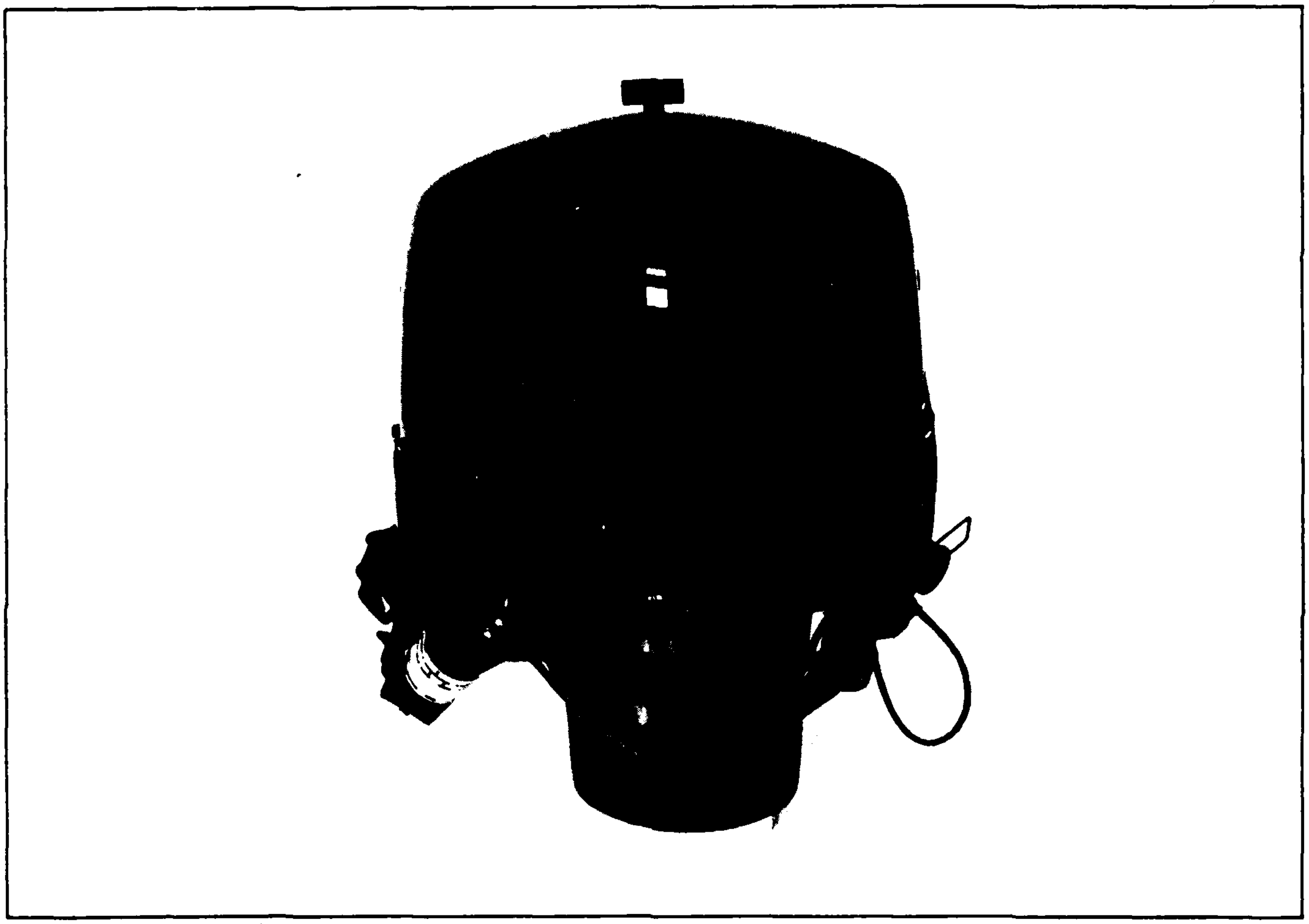

Figure 1. The AH-64 helmet.

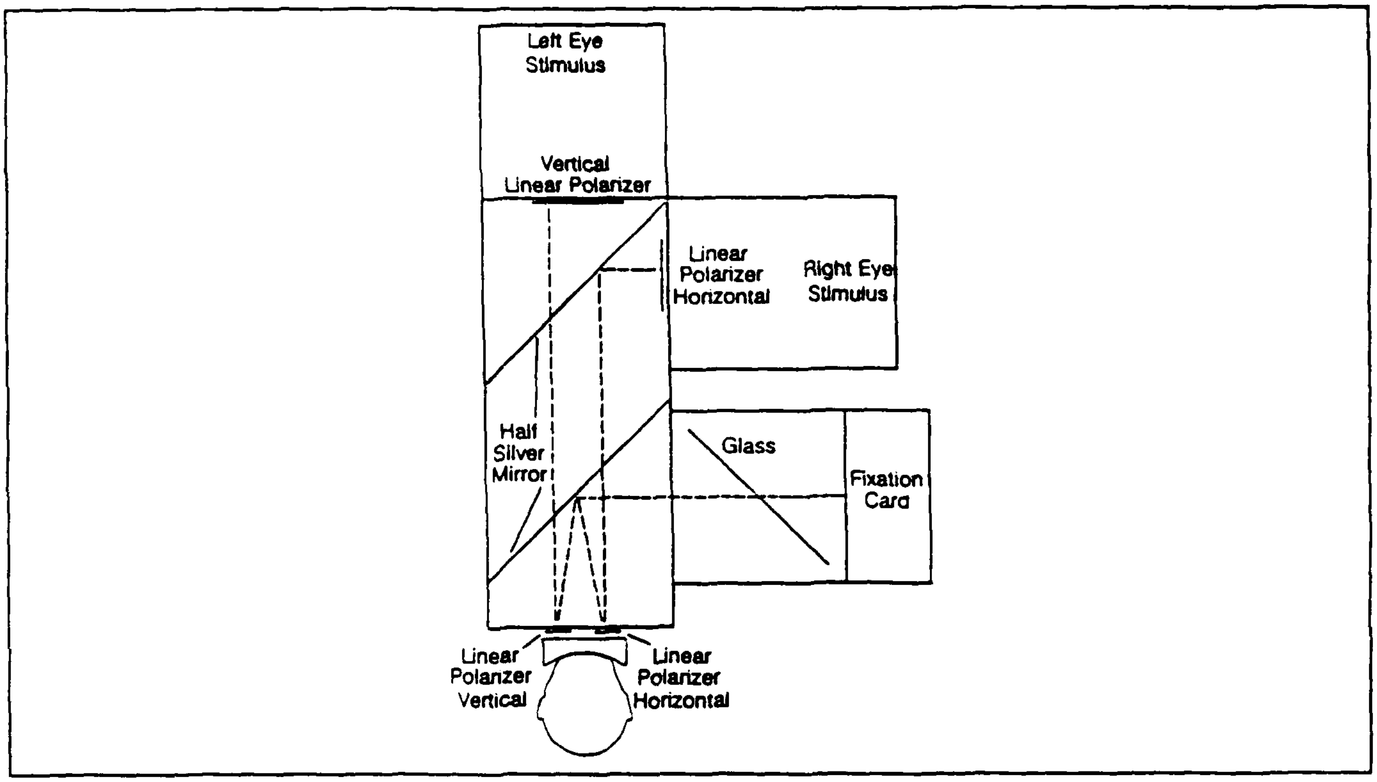

Figure 2. A 3-field tachistoscope.

H C	V P	Q R	K L
P W	V S	M R	K L
No match	Left match	Right match	Double match

Figure 3. An example of each of the stimulus cards.

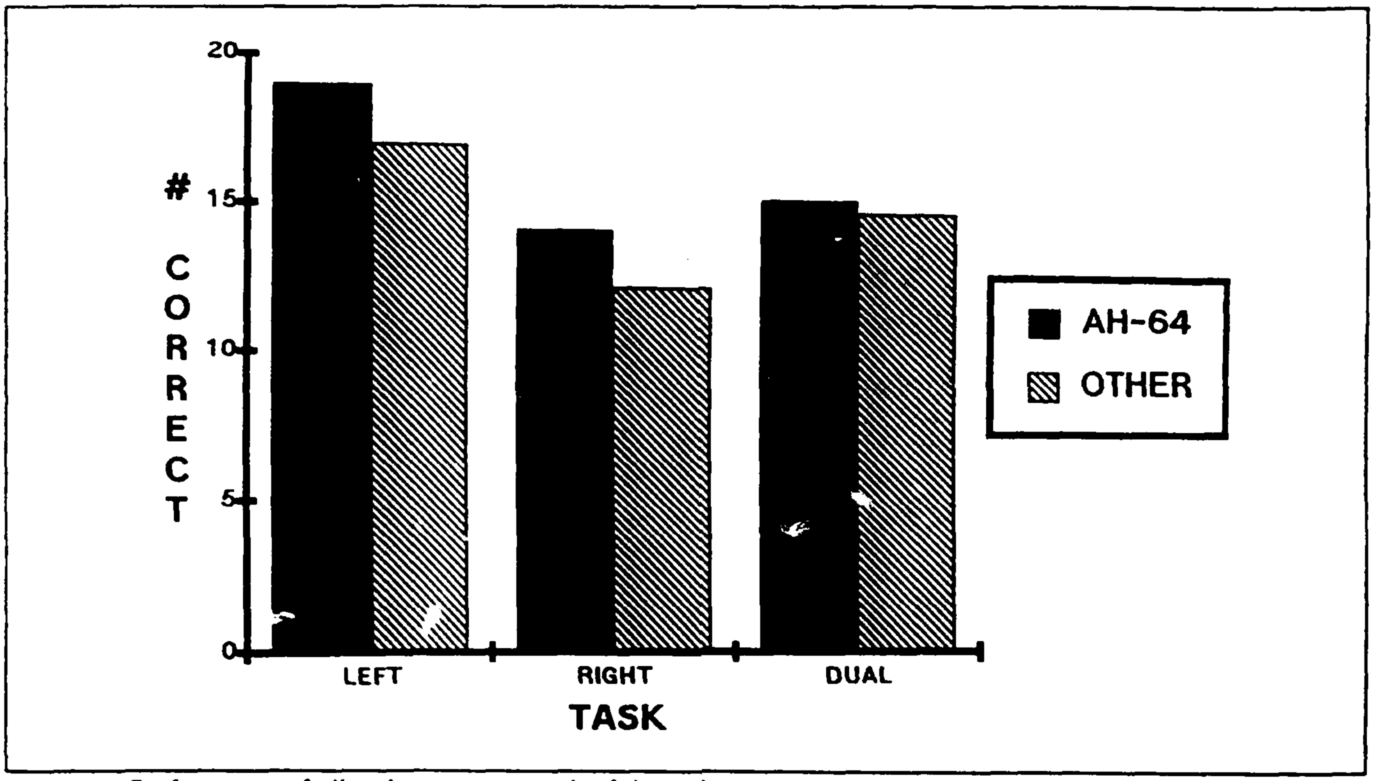

Figure 4. Performance of pilots by group on each of the tasks.

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